

Remarks

Reconsideration of this Application is respectfully requested.

Claims 1-2, 4, and 6-9 are pending in the application, with claim 1 being the independent claim. Claims 3 and 5 have been cancelled. Claim 1 has been amended. Support for the amendment to claim 1 can be found throughout the specification, e.g., at paragraph [0008]. These changes are believed to introduce no new matter, and their entry is respectfully requested.

Based on the following remarks, Applicants respectfully request that the Examiner reconsider all objections and rejections and that they be withdrawn.

Rejections of claims 1-7 and 9 under 35 U.S.C. § 103(a)

Claims 1-7 and 9 were rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Hwang *et al.* (*J. Mater. Chem.* 11:1722-1725 (2001)) in view of Smalley *et al.* (*J. Nanosci. Nanotech* 3:81-86 (2003)). Specifically, the Examiner alleged that Hwang describes a process for forming a carbon nanotube reinforced ceramic nanocomposite by sonication of the CNT solution for 10 minutes. The Examiner acknowledged that Hwang does not provide for an extended sonication period of 2 to 10 hours. The Examiner alleged that Hwang teaches that a stable and homogenous suspension is critical, and that said suspension is achieved through the sonication step. For evidence of this allegation, the Examiner alleged that Smalley describes the relationship between sonication time and CNT dispersion for time periods up to 5 hours. Applicants respectfully traverse.

Based on the Supreme Court decision in *KSR International Co. v. Teleflex Inc.*, 127 S. Ct. 1727 (2007) ("*KSR*"), and current USPTO Examination Guidelines, the proper objective analysis for determining obviousness under 35 U.S.C. § 103 is as stated in *Graham v. John Deere Co. of Kansas City*, 383 U.S. 1, 17 (1966) ("*Graham*"). *See also*, Examination Guidelines for Determining Obviousness Under 35 U.S.C. § 103 in view of the Supreme Court Decision in *KSR International Co. v. Teleflex Inc.*, 72 Fed. Reg. 57526 (Oct. 10, 2007) ("Examination Guidelines"). Under this analysis, obviousness is a question of law based on underlying factual inquiries. The factual inquiries enunciated by the Court include: (1) determining the scope and content of the prior art; (2) ascertaining the differences between the claimed invention and the prior art; and (3) resolving the level of ordinary skill in the pertinent art. *KSR* did not remove the legally established requirement that each element of each claim must be taught in the documents cited by the Examiner.

In ascertaining the differences between the claimed invention and the prior art, it is well-established that a prior art reference must be considered in its entirety (*i.e.*, **as a whole**), including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 220 USPQ 303 (Fed. Cir. 1983). *See also* MPEP § 2141.02(VI). *See also* Examination Guidelines at 57528.

As noted by the Examination Guidelines: "In short, the focus when making a determination of obviousness should be on what a person of ordinary skill in the pertinent art would have known at the time of the invention, and on

what such a person would have **reasonably** expected to have been able to do in view of that knowledge." *Id.* at 57527 (emphasis added).

Claim 1 is the independent claim. Claims 2-7 and 9 are dependent on claim 1.

A. Hwang does not describe a dispersion consisting essentially of the carbon nanotubes, water-soluble salts, and dispersion medium.

Amended claim 1 recites a method of producing ceramic nanocomposite powder, wherein a dispersion is sonicated for 2 to 10 hours, and the dispersion consists essentially of carbon nanotubes, water-soluble salts, and dispersion medium, wherein the dispersion medium is selected from the group consisting of water, ethanol, nitric acid solution, toluene, N,N-dimethylformamide, dichlorocarbene, and thionyl chloride. Hwang does not teach sonicating a dispersion consisting essentially of carbon nanotubes, water-soluble salts, and dispersion medium. Hwang utilizes a detergent in his sonicated dispersion:

In a typical experiment, 6 mg of CNTs were added to 40 ml, 1.2 mM cetyltrimethylammonium bromide (C₁₆TMAB, 99+%, ACROS) aqueous solution, followed by ultrasonication to disperse the CNTs.

Hwang, pg. 1722, 1st col., last ¶. Hwang teaches the addition of a detergent (cationic surfactants such as C₁₆TMAB) to the carbon nanotubes in the dispersion, to "form co-micelle structure with surfactant molecules (vide infra) via strong van der Waals interactions," and that the co-micelles "were used as templates for the synthesis of silicon dioxide glass rods by addition of sodium silicate to the CNT-surfactant aqueous solution." Hwang, pg. 1722, 2nd col., last ¶.

Likewise, Smalley also teaches the use of surfactants. In Smalley, the unbundling of carbon nanotubes in the presence of surfactants was investigated. Figure 1 of Smalley represents the Raman spectrum in the absence and presence of surfactant (SDS). Figure 2 represents the increased fluorescence intensity resulting from addition of surfactant (SDS). The dispersion containing carbon nanotubes is only sonicated for short amounts of time in the absence of surfactant. Additionally, the dispersion of Smalley contains only water, and does not teach a dispersion with water-soluble salts. Thus, since neither Hwang nor Smalley teach or suggest sonicating for 2 to 10 hours a dispersion consisting essentially of carbon nanotubes, water-soluble salts, and dispersion medium, each and every element of claim 1 cannot be found in Hwang and Smalley, either individually or collectively. For at least this reason, Applicants respectfully request that the rejection of claims 1-7 and 9 under 35 U.S.C. §103(a) be withdrawn.

B. Sonication of the present invention promotes chemical bonding between the carbon nanotubes and the ceramic.

The presently claimed invention allows dispersion of CNTs in any dispersible solvent in the absence of a surfactant, and promotes chemical bonding between carbon nanotubes and water-soluble salts via sonication for 2 to 10 hours.

While not being bound by any particular theory, Applicants have shown that extended sonication activates the surface of the carbon nanotubes. In the case of a dispersion containing carbon nanotubes and a Cu salt, Applicants have shown

that Cu-oxygen bonding is generated from the Cu ions and the carboxyl or hydroxyl groups on the functionalized CNT surface. See *Advanced Materials* 17:1377-1381 (2005), attached in the accompanying third supplemental IDS as document AR5. Applicants elucidate that such chemically-bonded oxygen atoms present at the carbon nanotube/Cu interface play an important role as atomically transient agents accommodating the extraordinary load transfer between carbon nanotubes and the Cu matrix.

Hwang does not sonicate for an extended period of time. Thus, Hwang does not disclose the chemical bonding resulting from the extended sonication. The Examiner alleged that Hwang

discloses that "it can be deduced that the mechanical strength of the SiO₂-CNT glass rods is stronger than the interactions between the glass rods and the matrix" (pg 1725, col. 1, lines 13-28). It follows from this disclosure that The CNTs in fact do form a 'chemical bond' or a chemical interaction with the ceramic matrix material as presently claimed in Applicants amended claim 1.

Office Action, pg. 6, 1st ¶. Moreover, Examiner alleged that he could "find substantially no evidence to support Applicants allegation that chemical bonding of any form between the matrix and the CNTs is precluded under the Hwang process." Office action, pg. 10, last ¶- pg. 11, 1st ¶.

Applicants bring to the Examiner's attention that the statement by Hwang does not suggest, *either positively or negatively*, bond strength between the carbon nanotubes and their SiO₂ coating. Rather, the Hwang statement only serves to demonstrate that the mechanical strength of the microrods (carbon nanotubes coated with SiO₂) is *relatively* greater than the interface strength

between the microrods and the SiO₂ matrix. See Hwang, pg. 1725, ll. 5-7. This is certainly not an indicator (either positively or negatively) of the formation of chemical bonds within the microrod when the hardness of the SiO₂ matrix is significantly low.

When the carbon nanotubes chemically bond the ceramic matrix as presently claimed, mechanical properties (such as hardness and fracture toughness) of the composite increase with increasing carbon nanotube volume percentage. See *Scripta Materialia* 53:793-797 (2005) ("*Scripta*"), attached in the accompanying third supplemental IDS as document AS5. Figure 1a of *Scripta* supports the distinction of the present invention, wherein C-Al-O bonding is evidenced by a remarkable bending peak in the FT-IR spectrum of the nanocomposite after completion of drying and calcination processes. In particular, the C-Al-O bonds in the material exhibited a very sharp peak from 500 to 750 cm⁻¹, which is present only after oxidation is complete. Hence, Applicants wish to emphasize the extraordinary strengthening effect by load transfer due to the strong chemical bonding between carbon nanotubes and the matrix in the powders of the present invention.

As stated previously, the Examiner pointed to pg. 1725, col. 1, ll. 13-28 as evidence of chemical bonding. The Examiner's attention is directed to Figure 4 of Hwang. Figure 4 represents the Vicker's hardness test of a SiO₂ matrix. The Vicker's hardness value of the SiO₂ matrix ranged from 100 to 350 in Figure 4. The typical Vicker's hardness values of a SiO₂ matrix (quartz) are 1103 to 1260. See, <http://www.matweb.com/search/DataSheet.aspx?MatGUID=8715a9d3d1a14>

[9babe853b465c79f73e&ckck=1](#) (accessed August 20, 2008). The reason for the lower hardness values in Hwang relative to known SiO₂ hardness levels may be due to the presence of microstructures, such as pores, as shown in Figure 1 of Hwang. The top right circle of Hwang has a black circle that looks like a pore. Based on the Vicker's hardness value and microstructure, it is doubtful the sintering (or densification) was complete, since pores appear to have formed. When the sintering is incomplete, bonding between SiO₂ microrods and SiO₂ powders can be very weak due to the porosities present at the reinforcement/matrix interface. If the sintering is complete, the interface between SiO₂-CNT rods and SiO₂ powders cannot be separated. See, Hwang, pg. 1725, col 1, lines 2-5.

Thus, Applicants have demonstrated the presence of chemical bonding in the present invention. The Examiner has provided no evidence that such chemical bonding exists in the composite materials of Hwang. In fact, the Examiner's deduction that "the mechanical strength of the SiO₂-CNT glass rods is stronger than the interactions between the glass rods and the matrix," is doubtful based on the low hardness of the Hwang SiO₂ matrix and its porous microstructure. For at least the above distinctions, Applicants respectfully submit that the claimed invention is not obvious and request that the rejection of claims 1-7 and 9 under 35 U.S.C. §103(a) be withdrawn.

C. The present invention discloses a method for fabricating ceramic nanocomposite powders.

Applicants wish to emphasize that the arguments presented by the Examiner related to the Hwang matrix mechanical properties refer to a matrix comprising microrods (carbon nanotubes coated with SiO₂), wherein the matrix further requires a process of bulking the microrods by mixing with general ceramic powders (SiO₂) to fabricate bulk ceramic composite materials. The present invention is NOT a fabrication of bulk ceramic composite materials as described by Hwang. Rather, the present invention is directed to ceramic nanocomposite *powders*. These powders can exhibit extraordinary strengthening effect to the strong chemical bonding at the interface between the carbon nanotubes and the ceramic matrix.

For at least the above distinctions, Applicants respectfully submit that the claimed invention is not obvious and request that the rejection of claims 1-7 and 9 under 35 U.S.C. §103(a) be withdrawn.

D. The present invention discloses a ceramic matrix not limited to the polymerized matrix of Hwang.

The present invention is directed to forming a chemical bond directly between the ions in the water soluble salt and the carbon nanotubes. In order to accomplish this objective, Applicants adopted a process of gradually converting the water-soluble salt into the ceramic matrix through drying and calcination instead of polymerization. Nanocomposite powders produced by the method of the present invention have improved characteristics. For example, as

demonstrated in *Scripta*, C-Al-O binding show remarkable bending peak in FT-IR after completion of the drying and calcinations process. See, e.g., *Scripta*, Figure 1a. More specifically, the C-Al-O bonding exhibited a sharper bending peak after oxidation than before oxidation at wave numbers 500 to 750 cm^{-1} .

Hwang uses a silicate salt as the ceramic matrix, since polymerization of the silicate is required to coat the carbon nanotubes. Hwang requires pH control to facilitate the polymerization. Ceramic matrices such as CuO are impossible to form using the method of Hwang, since polymerization cannot be achieved.

Since the method of the present invention produces a nanocomposite powder distinct from the bulk composite matrix of Hwang, one of skill in the art would not look to the method of Hwang to achieve the claimed method. For at least the above distinctions, Applicants respectfully submit that the claimed invention is not obvious and request that the rejection of claims 1-7 and 9 under 35 U.S.C. §103(a) be withdrawn.

Rejection of claim 8 under 35 U.S.C. § 103(a)

Claim 8 was rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over Hwang in further view of Chang (U.S. Pat. No. 6,420,293). Specifically, the Examiner alleged that Hwang teaches that the SiO_2 -CNT powder is to be calcinated in an N_2 atmosphere at 1050°C, which falls between the claimed temperature range of 400-1700°C. The Examiner acknowledged that Hwang fails to explicitly set forth that the calcination of the ceramic matrix should be performed under a high vacuum. However, the Examiner alleged that

Chang teaches that the heating of carbon nanotube materials at elevated temperatures in an oxidizing environment typically results in chemical changes in the surface of the particles, and that both N₂ atmospheres and high vacuum environments are commonly utilized as non-oxidizing environments. Thus, the Examiner alleged that the high vacuum environment would be an obvious alternative to the nitrogen atmosphere in Hwang. Applicants respectfully traverse this rejection.

Claim 8 is dependent on claim 1. Hwang does not describe the method of making a ceramic nanocomposite powder as featured in claim 1. Chang does not cure the deficiencies of Hwang. In view of these arguments, each and every element of claim 8 is not taught or suggested.

Even if, *arguendo*, Hwang and/or Chang describe the ceramic nanocomposite powder as described claim 1, Applicants submit that the calcination temperature of claim 8 is defined to achieve higher order objectives (or more complicated objectives) in addition to the basic objective such as prevention of carbon nanotube damage. For example, calcination under vacuum conditions can efficiently remove hydrated water contained in crystals of the ceramic matrix and accelerate crystallization of the ceramic matrix, leading to easy sintering during further sintering process.

Thus, neither Hwang nor Chang teach or suggest that calcination of the ceramic matrix should be performed under a high vacuum as required by claim 1, either individually or collectively. For at least the above argument, and in further view of the arguments for claim 1-7 and 9 filed herein, the rejection of claim 8

under 35 U.S.C. §103 as allegedly being obvious by Hwang in view of Chang should be withdrawn.

Conclusion

All of the stated grounds of objection and rejection have been properly traversed, accommodated, or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently outstanding objections and rejections and that they be withdrawn. Applicants believe that a full and complete reply has been made to the outstanding Office Action and, as such, the present application is in condition for allowance. If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided.

Prompt and favorable consideration of this Reply is respectfully requested.

Respectfully submitted,

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